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<p>(21) International Application Number: PCT/EP91/00451</p> <p>(22) International Filing Date: 9 March 1991 (09.03.91)</p> <p>(30) Priority data: 494,120 15 March 1990 (15.03.90) US</p> <p>(71) Applicant (<i>for all designated States except US</i>): THOMSON CONSUMER ELECTRONICS S.A. [FR/FR]; 9, place des Vosges, La Défense 5, F-92400 Courbevoie (FR).</p> <p>(72) Inventors; and            (75) Inventors/Applicants (<i>for US only</i>) : SAVATIER, Tristan [FR/US]; 535 Gayley Avenue, Apt. 214, Los Angeles, CA 90024 (US). DELPUCH, Alain [FR/US]; 2044 Pelham Avenue, Los Angeles, CA 90025 (US).</p>		<p>(74) Agent: EINSEL, Robert; Deutsche Thomson-Brandt GmbH, Patents and Licensing, Göttinger Chaussee 76, D-3000 Hannover 91 (DE).</p> <p>(81) Designated States: AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH (European patent), CM (OAPI patent), DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GA (OAPI patent), GB (European patent), GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL (European patent), NO, PL, RO, SD, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US.</p> <p><b>Published</b>  <i>With international search report.</i>  <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	
<p>(54) Title: DIGITAL IMAGE PROCESSING INCLUDING BLOCK EDGES FILTERING</p> <p>(57) Abstract</p> <p>In a coder frames of a digital video signal are scanned to get blocks of pixels, motion vectors are estimated and block errors are calculated using the decoded foregoing frame, thereby providing an intra/inter decision signal and intraframe-blocks of pixel values or motion compensated interframe-blocks of pixel difference values depending on the result of the block error. The blocks of pixel values and pixel difference values, respectively, are transformed with a DCT to blocks of coefficients, coded together with the motion vectors in a Huffman coder with variable word length. The resulting groups of coded coefficients are quantized individually by the use of a quantization level and the coded coefficients of the group are individually quantized by the use of a quantization matrix, controlled by the fullness of a buffer. In decoder groups of coded coefficients which belong to blocks of pixels are de-quantized individually by the use of an encoding quantization level and each coded coefficient of each group is de-quantized individually by the inverse use of an encoding quantization matrix, controlled by the fullness of a buffer. The groups of coded coefficients and motion vectors are decoded in a Huffman decoder with variable wordlength, thereby providing blocks of decoded coefficients. The blocks of decoded coefficients are transformed with an inverse DCT to pixel values and pixel difference values, respectively, out of which blocks of pixels out of intraframe-blocks of pixel values and motion compensated interframe-blocks of pixel difference values, respectively, are generated depending on an intra/inter decision signal, thereby evaluating the motion vectors. The blocks of pixels are filtered at their boundaries, if the according adjacent block has not nearly the same motion vector, and are inserted again in frames of a digital video signal in an according order. The decoded blocks of coefficients are filtered in both, coder and decoder. The visibility of coding artefacts is thereby reduced.</p>			

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## Digital Image Processing Including Block Edges Filtering

## Background of the invention

The present invention relates to digital image processing using block edges filtering.

A large number of coding/decoding methods for full-motion digital images have been proposed in recent years.

Because the available data rate in present transmission channels and storage media is limited it is an object of these coding methods to reduce the data rate of the coded and transmitted or stored video signal.

For the purpose of storing digital motion images on optical storage media, e.g. CD-ROM, MOD (Magneto Optical Disc), a maximum video data rate of about 1.2 Mbits/s is allowed.

One general example of a system for coding and decoding digital video signals is disclosed in "Scene Adaptive Coder", W.H. Chen, W.K. Pratt, IEEE Transactions on Communications, Vol. COM-32, No. 3, issued in March, 1984 in which scene adaptive coding/decoding of video signals is described, using DCT (discrete cosine transform), a variable threshold for the DCT coefficients, quantization, Huffman-coding and a buffer in the coder and a buffer, Huffman decoder, threshold adding and inverse DCT in the decoder.

In US Patent No. 4,785,349 in a similar way regions of a frame are coded separately. In addition, motion compensation is performed using this regions.

In both systems the fullness of the buffer controls the threshold and the quantizer step size, respectively. It is to be made sure that the buffer will have no overflow or underflow within the present frame. This causes a varying quantizer step size and a consequently varying image quality

within each frame. But if blocks and regions, respectively, are coded and decoded including data rate reduction, artefacts (blocking effects) will arise after decoding at the boundaries of these blocks and regions, respectively.

#### Summary of the invention

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It is an object of the present invention to make artefacts at block edges invisible in case of motion compensated digital images and to improve the image quality of the decoded images.

A sequence of digital images is coded using differential coding. The  $n$ th image of the sequence is partitioned in blocks  $B(n, i, j)$  of pixels, where  $i$  and  $j$  are the frame coordinates of the left top pixel of the block and  $n$  is a frame number.

The temporal correlation between the image content of frame  $n$  and frame  $n-1$  is used to code each block in frame  $n$  as a displacement of the most similar block in frame  $n-1$ .

$V(n, x, y)$  is called the displacement of the block  $B(n, i, j)$  from frame  $n-1$  to frame  $n$ . This displacement is used as a predictor for the motion compensation. If  $B'(n, i, j)$  is the decoded block  $B(n, i, j)$ , then  $B'(n, i, j) = B'(n-1, i+x, j+y)$ .

$V(n, x, y)$  is computed by means of a search in the decoded frame  $n-1$  for a block, which minimizes the difference between  $B(n, i, j)$  and  $B'(n-1, i+x, j+y)$ . The steps for a coding loop are:

- (1) code frame  $n$  using motion compensation and the current predictor
- (2) decode frame  $n$
- (3) filter decoded frame  $n$

- (4) select the decoded and filtered frame n and calculate the current predictor
- (5) go to step (1) to code frame n+1

The decoding loop is build accordingly in a symmetrical manner.

The basic idea of the invention is to apply a filter within the decoding loop on the edges of the blocks to reduce the block effect. This filter improves the quality of the current image and reduces the propagation of blocking effect artefacts in subsequent images.

Another aspect of the invention is to apply this filter to a block edge only if the two adjacent blocks have different displacements. By doing this the resolution of the image is enhanced.

The advantages of the present invention will become more apparent from the following more detailed description when taken in conjunction with the accompanying drawings.

#### Brief description of the drawings

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Fig. 1 is a schematic block diagram of a coder

Fig. 2 is a schematic block diagram of a decoder

Fig. 3 shows an image with adjacent blocks of pixels

Fig. 4 shows a quantization matrix for luminance blocks

Fig. 5 shows a scanning order

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Fig. 6 shows a quantizer function graph

Description of the preferred embodiments

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The images have a medium resolution, e.g. 704 \* 288 pixels. The luminance component Y is coded for each of the pixels, whereas the color components U and V are coded in the form of macro-pixels, a macro-pixel being made of 4 luminance pixels.

Each frame is divided into macro-blocks of 16\*16 luminance pixels. Each macro-block is composed of:

- 4 blocks of 8\*8 pixels for Y,
- 1 block of 8\*8 macro-pixels for U,
- 1 block of 8\*8 macro-pixels for V.

A single 704 \* 288-image not encoded consists of:

- $(704 / 16) * (288 / 16) = 792$  macro blocks,
- $792 * 6 = 4752$  blocks,
- $4752 * 64 = 304128$  bytes.

Such a frame would occupy a size of about 300 KByte in the uncoded format, whereas the available bandwidth allows about  $(1.2 \text{ Mbit/s}) / (8 * 25 / \text{s}) = 6$  KByte per frame, i.e. less than 1/2 bit per pixel. A compression rate of about 1/50 is to be achieved.

In Fig. 1 an digital image source 11 is connected to a frame memory (a RAM) 12 which stores frame n. Sequentially each

block of pixels is then send to a motion compensation circuit 17.

As most of the time frame n-1 is very close to frame n, only the differences between frames n-1 and n are encoded. This technique is called interframe coding (delta-coding) and results in a relatively low data rate.

However in some cases it is necessary to encode a frame by itself, e.g. when there is a "cut" in the image sequence. This technique is called intraframe coding. It is also necessary to use intraframe coding to allow non-sequential decoding, e.g. start decoding from various points within an image sequence stored on a CD. But intraframe coding results in a higher data rate.

Because in case of motion in the image sequence interframe coding may yield no good quality of the coded image, moving pieces in the image sequence should be detected. Thereby the differences between the moving pieces from frame n-1 and the according pieces from frame n are minimized and the interframe coding leads to improved image quality. The purpose of motion compensation is to build an image as close as possible to frame n by only taking moving pieces out of frame n-1.

This is performed within motion compensation circuit 17 on a block basis: the block  $B(n, i, j)$  of frame n located at frame coordinates  $(i, j)$  is evaluated by copying the block  $B'(n-1, i+x, j+y)$  stored at frame coordinates  $(i+x, j+y)$  in a frame memory (a RAM) 142 which contains frame n-1. The displacement  $V(n, x, y)$  represents the apparent motion of the image at this point of screen. When using 8\*8 pixel blocks for motion compensation the displacement may have a precision of  $\pm 1$  pixel and a range of  $\pm 16$  pixel.

In case of non-random block scanning the motion compensation vectors are delta coded. The delta vectors (dx, dy) range from -32 to +32 and the most frequent value encountered is 0 (vector same as previous vector). The delta coordinates are coded independently with adapted Huffman codes in Huffman coder 154. As the statistics for dx and dy are not identical two Huffman codes are used.

Then the vectors are packed 4 by 4: As there is a big chance for dx and dy to be zero, the distribution of zero values among the 4 dx values is coded with an adapted Huffman code. Only the non-zero values of dx are coded after that (with another adapted Huffman code). The same technique is used for dy.

In order to optimise the size of the code for the motion compensation vectors, a certain tolerance is accepted. If  $V$  is the target block (not coded),  $V'$  is the block obtained by using the best motion compensation vector computed for  $V$ , and  $V'_o$  is the block obtained by using the previous motion compensation vector (the one which was used for the block left of  $V$ ), the previous motion compensation vector will be used again, if  $E(V'_o, V) < E(V', V) + E_o$ .

By choosing an appropriate threshold  $E_o$ , the number of delta vectors equal to zero can become very big, and the coding will be much more efficient because zero delta vectors are coded with very few bits. This leaves more room for the error correction.

Once a good approximation of frame  $n$  has been obtained from frame  $n-1$  by using motion compensation, the residual pixel differences remain to be encoded. To have an estimation of the difference between two blocks and to decide for each block, if motion compensated interframe coding or intraframe coding yields better image quality in connection with a given data rate, an error function (e.g. the quadratic error)

is evaluated in motion compensation circuit 17. The equation of the quadratic error is:

$$E(B, B') = \sum_{ii=0}^7 \sum_{jj=0}^7 (P(ii, jj) - P'(ii, jj))^2$$

where  $ii$  and  $jj$  are the coordinates within the blocks  $B(n, i, j)$  and  $B'(n-1, i+x, j+y)$ , respectively, of pixels  $P$  and  $P'$ , respectively, and  $E(B, B')$  is an estimation of the difference between block  $B(n, i, j)$  of frame  $n$  and block  $B'(n-1, i+x, j+y)$  of frame  $n-1$ .  $B(n, i, j)$  is the target block (not coded),  $B'(n-1, i+x, j+y)$  is the block obtained after interframe coding.

Motion compensation is worth being encoded only if:

$$E(B, B') < (1 / 2) * E(B, B_0)$$

$B_0$  is the block  $B(n-1, i+x, j+y)$  obtained only with motion compensation (not interframe coded).

If motion compensation is calculated for 8\*8 pixel blocks within a range of  $\pm 16$  pixels, the research for the best matching block is performed in a 40\*40 pixels area (33\*33 possible displacements). A brute force search is performed among all the possible displacements  $(x, y)$  and the displacement which corresponds to the minimum mean absolute error is chosen. This vector is transferred to a Huffman coder 154. Motion compensation circuit 17 may contain a memory in which this 40\*40 pixel area is stored.

The equation of the mean absolute error  $E_m$  is:

$$Em(B, B') = \sum_{ii=0}^7 \sum_{jj=0}^7 |P(ii, jj) - P'(ii, jj)|,$$

where  $ii$  and  $jj$  are the coordinates within the blocks  $B(n, i, j)$  and  $B'(n-1, i+x, j+y)$ , respectively, of pixels  $P$  and  $P'$ , respectively.  $B(n, i, j)$  is the target block (not coded),  $B'(n-1, i+x, j+y)$  is the block obtained after interframe coding. The Y component pixel values are used.

In theory the motion compensation should be performed in the decoded frame  $n-1$  for that is the one used at decoding time to build the next frame, but practically the source frame  $n-1$  is used instead of the decoded one.

Displacements obtained by using source images are easier to encode efficiently, because of the lower level of noise and of the better quality of the source images compared with decoded images. Random noise tends to generate a random factor in the displacements.

Motion compensation in principle is also described in US Patent No. 4,785,349, columns 27 - 29.

In case of intraframe coding the block  $B(n, i, j)$  of pixels of frame  $n$  is coded directly, in case of interframe coding the block  $B'(n-1, i+x, j+y)$  is subtracted from block  $B(n, i, j)$  in motion compensation circuit 17 and then coded. Frame memory 142 receives addresses from motion compensation circuit 17.

The resulting block of pixels or pixel differences, respectively, is transformed in a DCT circuit 151.

Each 8\*8 block of values representing spatial data (such as the luminance component Y) is transformed by a DCT into an

8\*8 block of spectral coefficients representing the frequency distribution in both, horizontal and vertical direction. The range of the coefficients in the transformed block is eight times the range of the values in the source block. The top-left coefficient of the transformed block is particular: it is the average value of the source block (multiplied by eight). This coefficient is called DC value, the other coefficients are called AC values. It appears that the DC coefficient is very important, and that even if a high quantization level is requested, there should be a minimum error on this value since an error on the average produces very noticeable artefacts (blocking effects).

Before being encoded further, the block is quantized in quantizer 152 by an algorithm chosen to trade off perceived image quality against bit rate. The algorithm of quantizer 152 is described by the following equations:

$$y = \begin{cases} \frac{x - T}{g} + 1 & \text{for } x \geq T, \\ 0 & \text{for } -T < x < T, \\ \frac{x + T}{g} - 1 & \text{for } x \leq -T, \end{cases}$$

where  $x$  is a DCT coefficient of the transformed block,  $y$  is the quantized coefficient,  $T$  is the threshold at which the output is forced to zero and  $g$  is the quantization step size. The values of  $T$  and  $g$  are chosen according to the available transmission or storage bandwidth. The according quantizer function graph is shown in Fig. 6.

The quantizer step size  $g$  depends on the position of the coefficient in the transformed block: high frequency coefficients will be quantized coarser than low frequency coefficients because lower frequency DCT coefficients are relatively less important in the perception of the subjective quality of the decoded image. The quantizer step size is obtained for each position in the block by scaling with a predefined quantization matrix  $Q$ . As an example, the quantization matrix used for  $Y$  is shown in figure 4. A different quantization matrix is used for  $U$  and  $V$ .

A minimum value should be defined for  $g$ , to guarantee that the quantized frequency coefficients are always in the range covered by the code used to encode them. As for threshold  $T$ , one may use  $T = g / 2$ .

In order to simulate the behaviour and the decoding error of a decoder (Fig. 2) and to correct the coding calculation within the coder (Fig. 1) accordingly, a feedback loop is built consisting of a de-quantizer 156, a DCT circuit 157 and a filter circuit 158. De-quantizer 156 performs the according inverse function of quantizer 152 and DCT circuit 157 an inverse DCT. The filter circuit 158 is used in order to eliminate source and quantization noise, glitches, isolated pixels, to reduce high frequencies which are hard to code and to reduce the propagation of block effect artefacts in subsequent images. The filter may be a median filter or a simple convolution filter, both two-dimensional with a  $3 \times 3$  pixels kernel. This kind of filters are well known by a man skilled in the art.

The filtered blocks  $B'(n-1, i, j)$  at the output of filter circuit 158 are stored in frame memory 142 which is also connected to motion compensation circuit 17. By this way the feedback loop is closed.

The quantized block consists usually of few important spectral components (statistically concentrated in the low horizontal and vertical frequencies), separated by a lot of zeros. Therefore the quantized DCT coefficients in the block are first folded, thereby transformed in a linear list containing alternatively a run of  $r$  zeros ( $r$  may be equal to 0) and a non zero coefficient and are then encoded with variable wordlength (runlength coding) together with the displacements in the Huffman coder 154.

The folding of each of the matrices of 64 DCT coefficients is performed in a sorter 153 accordingly to the order shown in Fig. 5. The sorting starts with coefficient No. 1, which is the DC coefficient, is continued in a viceversa diagonal manner and ends with coefficient No. 64. This kind of sorting is called 'zigzag scanning'. After the last coefficient of the present block an End-of-Block code (EOB) is added.

The zigzag order can be chosen in order to increase the probability of having a very long run of zero coefficients until the end of the block. Because the EOB code is a frequent event, it is coded with few bits.

The optimal zigzag order depends on the quantization method and of the code used subsequently.

Zigzag scanning and runlength coding are described in principle in the above mentioned article "Scene Adaptive Coder" by Chen and Pratt.

The Huffman code for encoding the runs of zeros with a maximum efficiency contains 64 possible runs of  $r$  zeros ( $r$  ranging from 0 to 63). An additional code is reserved for the EOB sign. The code defined for each run of zeros is totally independent of the value that follows the run.

Another Huffman code encodes the non-zero coefficients with a maximum efficiency. The range covered by this code is [-256, -1] and [+1, +256].

As quantized non-zero coefficients have an important probability to be  $\pm 1$ , particularly in the higher frequency coefficients because they are more strongly quantized, a special code has been reserved to code a terminal run of  $\pm 1$  values. The signs of the non-zero coefficients are always coded with one bit, as their event may be considered as random with a 50% probability.

The Huffman coded data are stored in the buffer within buffer circuit 155 with a variable data rate and read out with a constant data rate. A channel coder 16 receives these data together with other signals.

In order to guaranty the data rate and to avoid buffer overflow or underflow the quantization step size of quantizer 152 and de-quantizer 156 is adapted by means of a quantization level, which is recalculated after each block has been encoded within buffer circuit 155 as a function of the amount of the already encoded data for the frame, compared with the total buffer size. This way quantization level can advantageously be recalculated by the decoder and does not need to be transmitted.

The scanning of the blocks, e.g. 32, 33, 34, 35, 36, within the present frame 31 is performed normally row by row and column by column.

Advantageously the scanning may be performed in a pseudo-random fashion to have a better estimation of the overall quantization level for a frame to achieve a certain data rate. The pseudo-random block scanning order can be changed for each frame to get even better results. In this case the

kind of block scanning will be transmitted and stored, respectively, too.

The channel coder 16 adds the inter/intra-information and the Huffman coded motion compensation information and e.g. pseudo-random address information, audio signals, error correction information and sync words to the video data stream.

Clock Generator 191 supplies control circuit 192 with clock pulses. Control circuit 192 supplies all the other circuits in the coder with appropriate control signals.

In Fig. 2 a channel decoder 26 receives the storage media or transmission channel data stream. This data stream is split into luminance and chrominance signals (Y, U and V), motion compensation information, inter/intra-decision information, audio signals, sync words and, if required, pseudo random block addresses. In addition error correction is performed within channel decoder 26.

The video signal, e.g. the luminance component, is fed with a constant data rate together with the Huffman coded displacements into buffer circuit 255 and transferred with a variable data rate from this buffer to a Huffman decoder 254. In this circuit the according decoding of the different Huffman codes, the special code for a terminal run of  $\pm 1$  values and EOB code is performed.

In the inverse sorter 253 an inverse scanning according to sorter 153 and Fig. 5 is performed. At the output are blocks of quantized 8\*8 DCT coefficients available. In de-quantizer 252 the coefficients are expanded approximately to their value at the input of quantizer 152 in the coder. This includes an inverse scaling according to quantization matrix  $Q$  (Fig. 4). The quantization level in de-quantizer 252 is controlled

by the fullness of the buffer and recalculated in buffer circuit 255 and does not need to be transmitted.

A DCT circuit 251 performs an inverse DCT on the 64 coefficients of each block.

The pixel values and pixel difference values, respectively, of the blocks are transferred to a filter 258. This filter may have a frequency response according to the response of filter 158 in the coder.

The output of filter 258 is transferred to motion compensation circuit 27. The motion compensation information and inter/intra-decision information from channel decoder 26, too, is fed to the motion compensation circuit 27. The displacements may address a frame memory (a RAM) 242 for frame n-1. In case of intraframe coding of the present block the output signal from frame memory 242 is not added and in case of interframe coding this output signal is added (motion compensated) to the pixel difference values in motion compensation circuit 27.

The (motion compensated) blocks are transferred from motion compensation circuit 27 to a second filter circuit 259. In this filter block edges filtering is performed. Because each block is coded separately, there may arise visible discontinuities at the boundaries of these blocks. Therefore in the second filter 259 the block edges become filtered horizontally or vertically, respectively. Let

$x_0, x_1, x_2, x_3, x_4, x_5, x_5, x_6, x_7, x_8, x_9 \dots$

be a line of pixels. Pixel  $x_0$  to pixel  $x_7$  belong to a first block, e.g. block 32 in Fig. 3, pixel  $x_8, x_9$  and so on belong to a horizontal adjacent second block, e.g. block 33.

Then pixel  $x_7$  is recalculated (filtered) as e.g.

$x_7 = (x_6 + 2 * x_7 + x_8) / 4$  and pixel  $x_8$  is recalculated as

$x_8 = (x_7 + 2 * x_8 + x_9) / 4$ .

Advantageously this filtering (horizontal and vertical) for block 32 and block 33, respectively, is only carried out, if one or more of the according adjacent blocks 33 - 36 have a distinct displacement. This leads to an improved resolution at the block boundaries.

Therefore motion compensation circuit 27 may contain a pixel and a displacement memory and control the second filter circuit 259.

The output blocks of the second filter circuit 259 are stored in a frame memory (a RAM) 22 as frame n. Before storing the according blocks are written into frame memory 242 as frame n-1. In case of pseudo random block scanning memory 22 can be addressed by the additional transmitted or in the decoder generated pseudo-random block addresses.

Frame memory 22 can be read out pixel by pixel and line by line. The resulting signal can be displayed e.g. on a TV screen 21.

The processing for the chrominance components U and V is performed in a similar way. Filter coefficients and the quantization matrix may vary. As mentioned before the displacement calculation in motion compensation circuits 17 and 27, respectively, is carried out with the Y component only. Clock regeneration circuit 291 supplies control circuit 292 with clock pulses. Control circuit 292 supplies all the other circuits in the decoder with appropriate control signals.

## Claims

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1. Method of encoding digital image sequences, comprising the steps of:
  - scanning of frames of a digital video signal of a type in which each frame thereof comprises a plurality of blocks of pixels to get these blocks of pixels,
  - estimating motion vectors and calculating block errors (quadratic error and/or mean absolute error),
  - providing intraframe-blocks of pixel values or motion compensated interframe-blocks of pixel difference values depending on the result of the block error calculation and providing an intra/inter decision signal,
  - transforming the blocks of pixel values and pixel difference values, respectively, with a DCT to blocks of coefficients,
  - coding the blocks of coefficients and the motion vectors in a Huffman coder with variable word-length, thereby providing groups of coded coefficients,
  - quantizing each group of coded coefficients individually by the use of a quantization level and means for quantizing each coded coefficient of the group individually by the use of a quantization matrix, controlled by the fullness of a buffer.
2. Method as defined in claim 1, comprising the step of:
  - coding the motion vectors in the form of difference vectors with respect to the according foregoing vector.
3. Method as defined in claim 1 or 2, comprising the steps of:
  - inserting a feedback loop, consisting of de-quantizing and inverse DCT transforming after the quantizing step,

-using the resulting decoded coefficient blocks for motion estimation, error calculation and motion compensation.

4. Method of decoding digital image sequences which are encoded as defined in claim 1, 2 or 3, comprising the steps of:

-dequantizing the groups of coded coefficients which belong to blocks of pixels individually by the use of the encoding quantization level and de-quantizing each coded coefficient of each group individually by the inverse use of the encoding quantization matrix, controlled by the fullness of a buffer,  
-decoding the groups of coded coefficients and motion vectors in a Huffman decoder with variable wordlength, thereby providing blocks of decoded coefficients,  
-transforming the blocks of decoded coefficients with an inverse DCT to pixel values and pixel difference values, respectively,  
-generating blocks of pixels out of intra-frame-blocks of pixel values and motion compensated interframe-blocks of pixel difference values, respectively, depending on an intra/inter decision signal, thereby evaluating the motion vectors,  
-filtering the pixels at the boundaries of the blocks of pixels,  
-inserting the blocks of pixels in frames of a digital video signal.

5. Method as defined in claim 4, comprising the step of:

-filtering the pixels at the according boundaries of the blocks of pixels only if the motion vectors for the according blocks are not nearly identical.

6. Method as defined in one or more of the claims 2 to 5, comprising the step of:
  - filtering the blocks of the decoded coefficients in two spatial directions.
7. Apparatus for encoding digital image sequences, comprising:
  - means for providing a compressed digital video signal of a type in which each frame thereof comprises a plurality of blocks of pixels,
  - means for scanning the frames to get the blocks of pixels,
  - means for estimating motion vectors and means for calculating block errors,
  - means for coding the motion vectors in the form of difference vectors with respect to the according foregoing vector,
  - means for providing intraframe-blocks of pixel values or motion compensated interframe-blocks of pixel difference values depending on the result of the block error calculation and means for providing an intra/inter decision signal,
  - means for de-quantizing and inverse DCT transforming the quantized blocks of coefficients in a feedback loop where these blocks form an input signal for the means which perform motion estimation, error calculation and motion compensation,
  - means for transforming the blocks of pixel values and pixel difference values, respectively, with a DCT to blocks of coefficients,
  - means for coding the blocks of coefficients and the motion vectors in a Huffman coder with variable word-length, thereby providing groups of coded coefficients,
  - means for quantizing each group of coded coefficients individually by the use of a quantization level and

means for quantizing each coded coefficient of the group individually by the use of a quantization matrix, controlled by the fullness of a buffer.

8. Apparatus for decoding digital image sequences, comprising:

- means for de-quantizing groups of coded coefficients which belong to blocks of pixels individually by the use of an encoding quantization level and means for de-quantizing each coded coefficient of each group individually by the inverse use of an encoding quantization matrix, controlled by the fullness of a buffer,
- means for decoding the groups of coded coefficients and motion vectors in a Huffman decoder with variable wordlength, thereby providing blocks of decoded coefficients,
- means for transforming the blocks of decoded coefficients with an inverse DCT to pixel values and pixel difference values, respectively,
- means for generating blocks of pixels out of intra-frame-blocks of pixel values and motion compensated interframe-blocks of pixel difference values, respectively, depending on an intra/inter decision signal, thereby evaluating the motion vectors,
- filtering means for the pixels at the according boundaries of the blocks of pixels which filter the according pixels if the motion vectors for the according blocks are not nearly identical,
- means for inserting the blocks of pixels in frames of a digital video signal in a pseudo-random order.

9. Apparatus as defined in claims 7 or 8, comprising:

- means for filtering the blocks of the decoded coefficients in two spatial directions.

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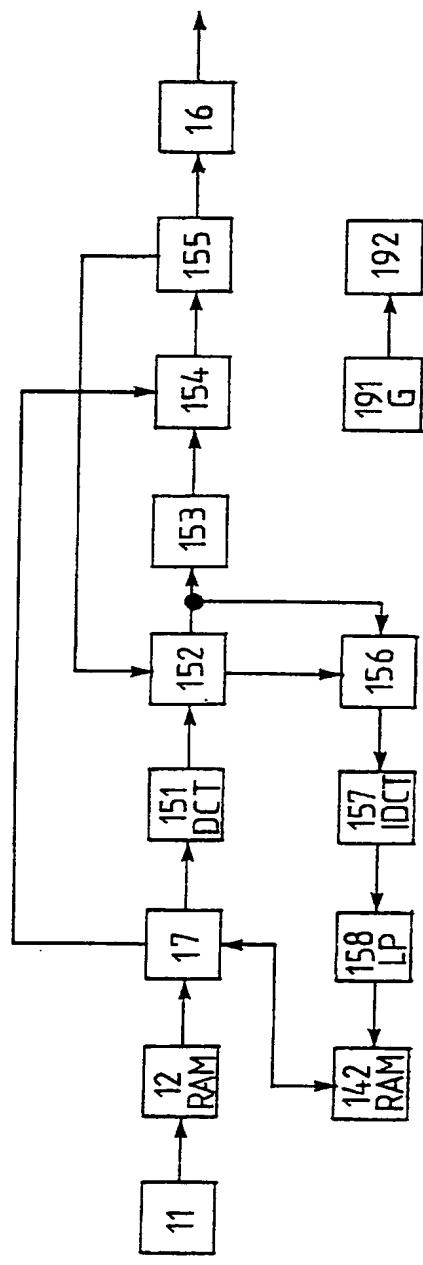


FIG.1

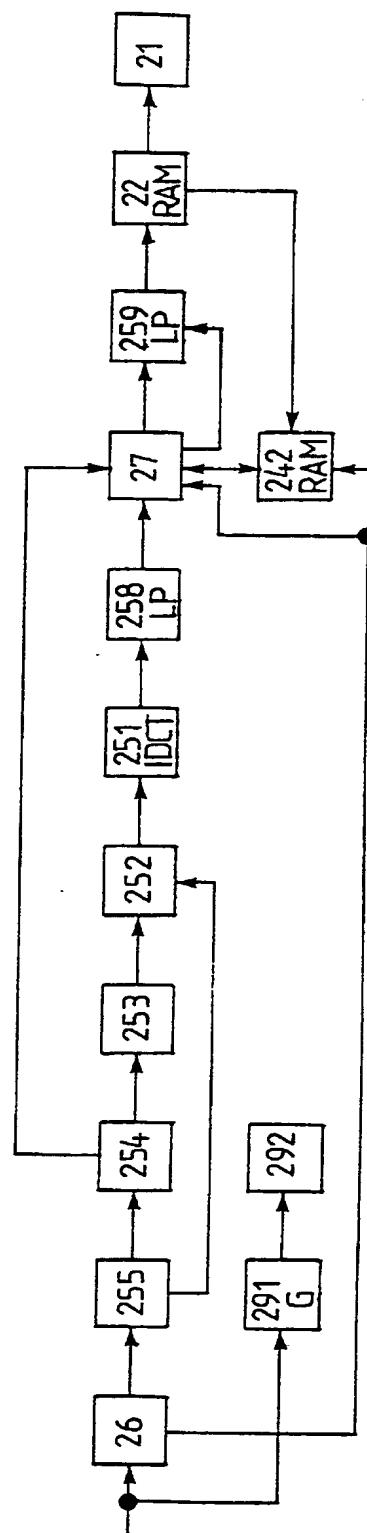
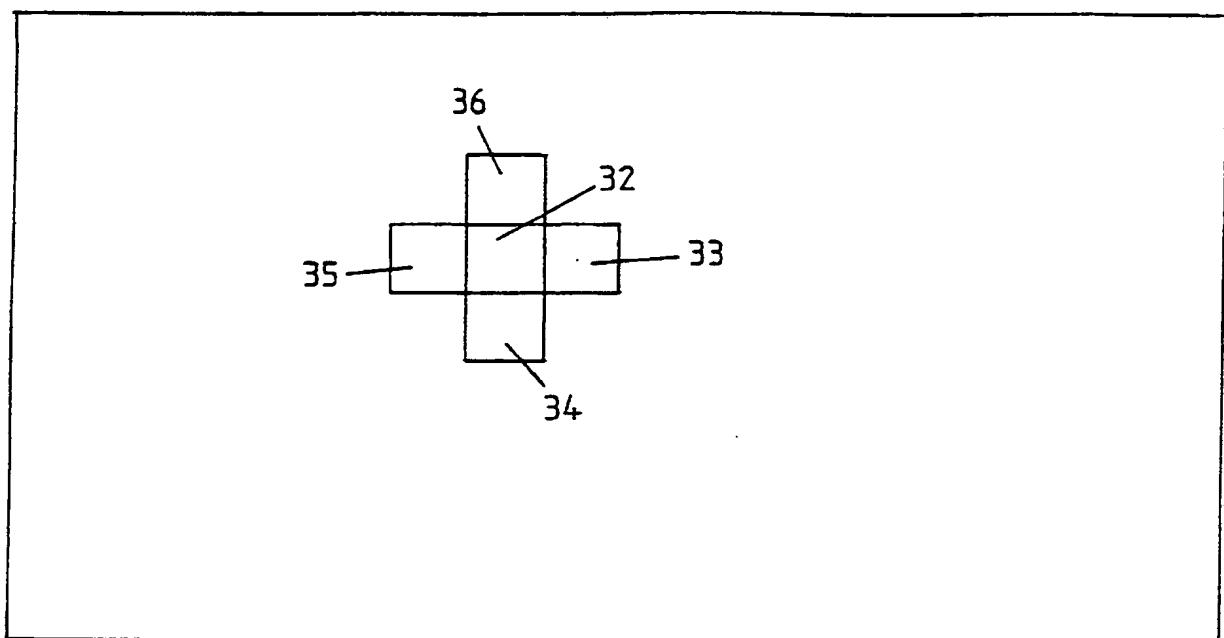


FIG.2



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FIG.3

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

FIG.4

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1	3	4	10	11	21	22	36
2	5	9	12	20	23	35	37
6	8	13	19	24	34	38	49
7	14	18	25	33	39	48	50
15	17	26	32	40	47	51	58
16	27	31	41	46	52	57	59
28	30	42	45	53	56	60	63
29	43	44	54	55	61	62	64

FIG.5

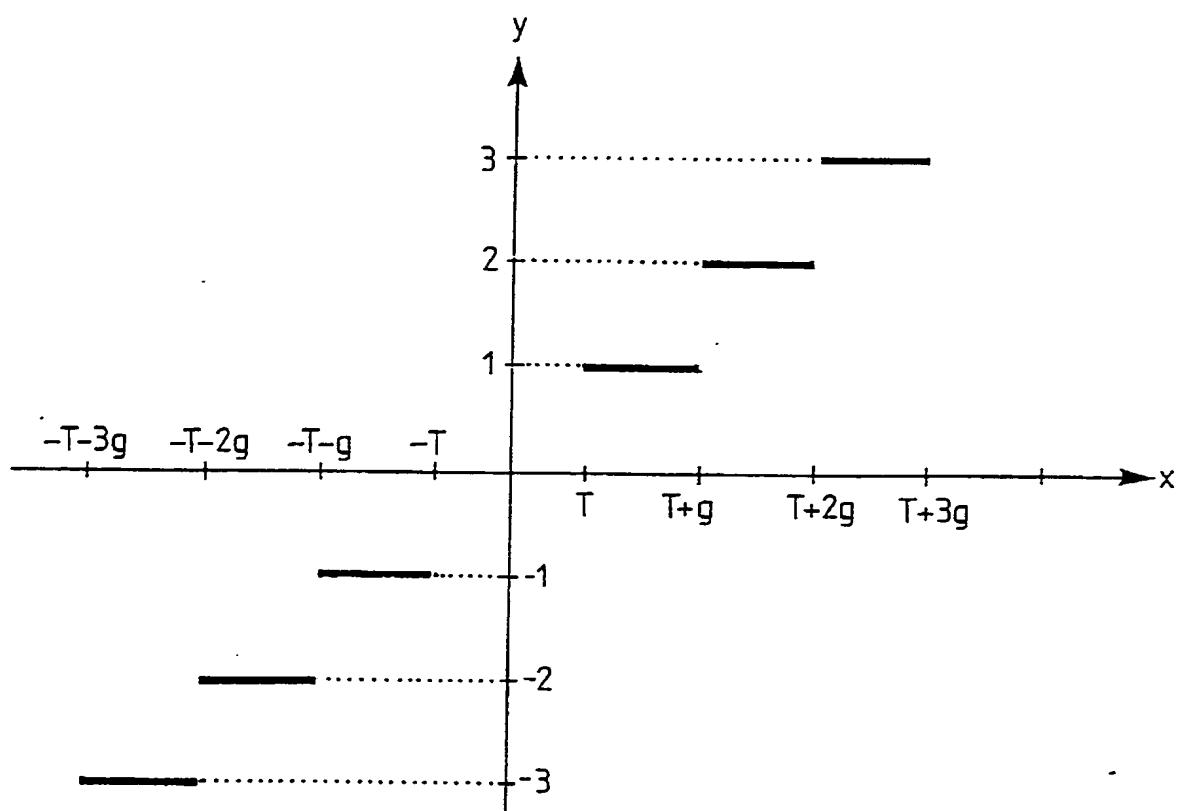


FIG.6

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 91/00451

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) <sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC

**IPC<sup>5</sup>:** H 04 N 7/133

## II. FIELDS SEARCHED

Minimum Documentation Searched <sup>7</sup>

Classification System	Classification Symbols
IPC <sup>5</sup>	H 04 N

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>

## III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup>

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
Y	NTZ Nachrichtentechnische Zeitschrift, volume 42, no. 3, March 1989, (Berlin, DE) D. Biere et al.: "Video-Codec und Endgeräte für das ISDN-Bildtelefon", pages 136-138,140-142,144,145 see the whole article --	1,3,4,7
Y	US, A, 4704628 (W. CHEN et al.) 3 November 1987 see column 13, lines 1-40 --	1,3,4,7
A	US, A, 4394774 (R. WIDERGREN et al.) 19 July 1983 see column 8, line 24 - column 11, line 43 --	1,3,4,7
A	Proceedings of SPIE, volume 1244, "Image Processing Algorithms and Techniques" (Santa Clara, California), 12-14 February 1990, --	1,3,4,7

- Special categories of cited documents: <sup>10</sup>
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

29th June 1991

Date of Mailing of this International Search Report

29.08.91

International Searching Authority

EUROPEAN PATENT OFFICE

Signature of Authorized Officer

F.W. HECK

## III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, " with indication, where appropriate, of the relevant passages	Relevant to Claim No.
Y	<p>C.A. Gonzales et al.: "DCT based video compression using arithmetic coding", pages 305-311      see the whole article</p> <p>--</p>	
Y	<p>IEEE Transactions on Circuits and Systems, volume 35, no. 2, February 1988, IEEE, (New York, NY, US),      H. Gharavi: "Low bit-rate video transmission for ISDN application", pages 258-261      see page 260, paragraph 2.4, "Quantization", see the whole document</p> <p>--</p>	1,3,4,7
A	<p>International Conference on Communications, Conference Record, volume 2 of 3, (Seattle, WA, US), 8-12 June 1980,      K.N. Ngan et al.: "Lowpass filtering in the cosine transform domain", pages 31.7.1 - 37.7.5      see the whole document</p> <p>--</p>	1,3,4,7
A	<p>US, A, 4754492 (H. MALVAR)      28 June 1988      see column 5, line 16 - column 12, line 7</p> <p>--</p>	1,4-6,8,9
A	<p>FR, A, 2606187 (THOMSON GRAND PUBLIC)      6 May 1988      see the whole document</p> <p>--</p>	1,4-6,8,9
A	<p>AEU, Archiv für Elektronik &amp; Übertragungstechnik, volume 42, no. 4, July/August 1988, (Stuttgart, DE),      J. Speidel et al.: "Space and transform domain filtering in hybrid coders", pages 230-235      see the whole document</p> <p>--</p>	1,4-6,8,9
A	<p>Review of The Electrical Communications Laboratories, volume 36, no. 2, March 1988, Nippon Telegraph and Telephone corporation, (Tokyo, JP), N. Mukawa et al.: "384-kbit/s video Codec", pages 225-231      see the whole article</p> <p>./.</p>	1,3,4

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	<p>"Symposium Record on the 16th International TV Symposium", Broadcast sessions, (Montreux, CH), 17-22 June 1989</p> <p>K. Grotz et al.: "Image coding techniques for 64 kbit/s channels", pages 387-409</p> <p>see page 388, paragraph 2.2, "Structure of a still picture codec", complete</p> <p>---</p>	1,4,7
A	<p>Signal Processing, volume 19, no. 1, January 1990, Elsevier Science Publishers B.V., (Amsterdam, NL),</p> <p>H. Schiller et al.: "Efficient coding of side information in a low bitrate hybrid image coder", pages 61-73</p> <p>see page 66, paragraph 4, "Efficient motion vector coding", complete</p> <p>-----</p>	1-4,7

ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.

EP 9100451  
SA 45341

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 31/07/91. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A- 4704628	03-11-87	None		
US-A- 4394774	19-07-83	US-A- 4302775 US-A- 4385363	24-11-81 24-05-83	
US-A- 4754492	28-06-88	CA-A- 1255391 EP-A- 0224583 JP-T- 63500070 WO-A- 8607479	06-06-89 10-06-87 07-01-88 18-12-86	
FR-A- 2606187	06-05-88	EP-A- 0270405 WO-A- 8803346 JP-T- 1501115 US-A- 4903128	08-06-88 05-05-88 13-04-89 20-02-90	